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Life Cycle Assessment: Impact Assessment & Applications

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U.S. EPA Region X
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Institute for Environmental Research and Education

Rita Schenck

- Environmental non-profit (501c3)
- ***Supports Fact-based Environmental Decision-Making***
- Headquartered in Washington State
- Diverse funding base (private, public, business, fee-for-service)
- ***Strongly believes that Business must drive environmental improvement***

American Center for Life Cycle Assessment

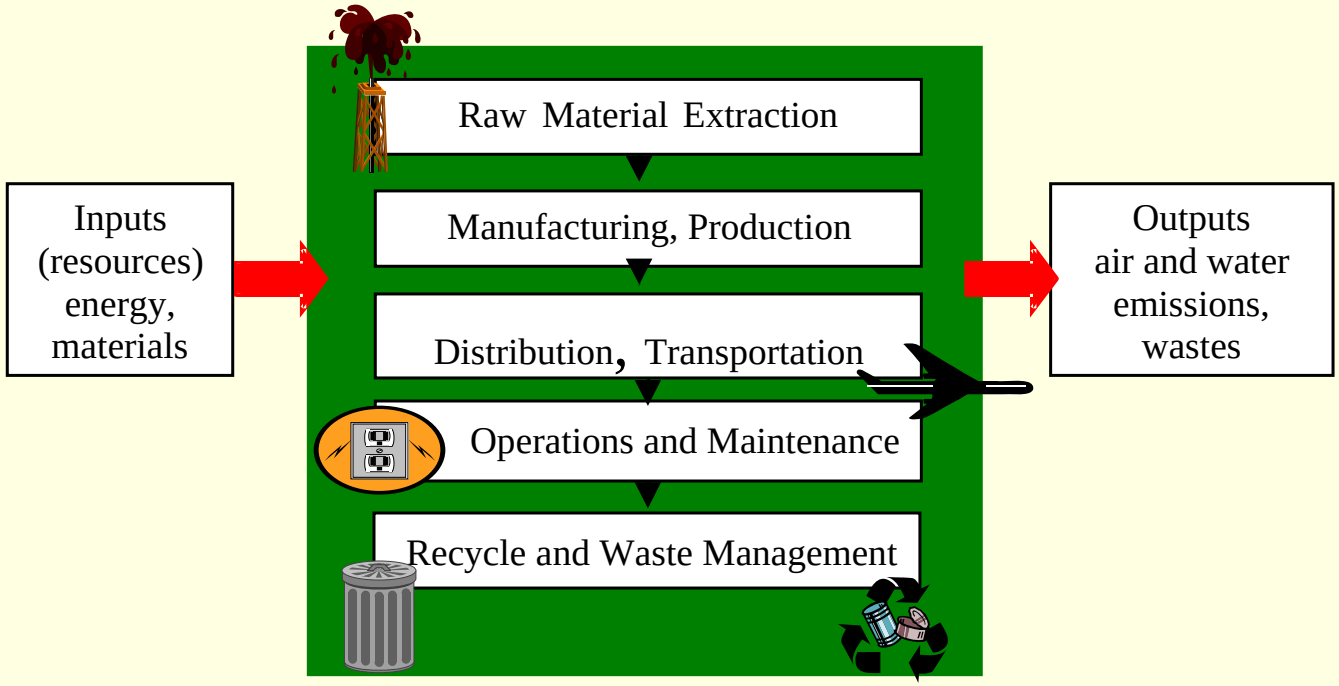
www.lcacenter.org

- Professional society for LCA in the USA
- Annual Conference, growing over 30% per year
- Next year in Portland November 2 – 5
- Certification for LCA Professionals

What we will cover today

- Life Cycle Impact Assessment
  - Environmental impact categories
  - Environmental mechanisms
  - Impact models
  - Required steps of the LCIA
  - Non-mandatory steps
- Life cycle interpretation
  - Sensitivity analysis
- Applications of LCA to policy

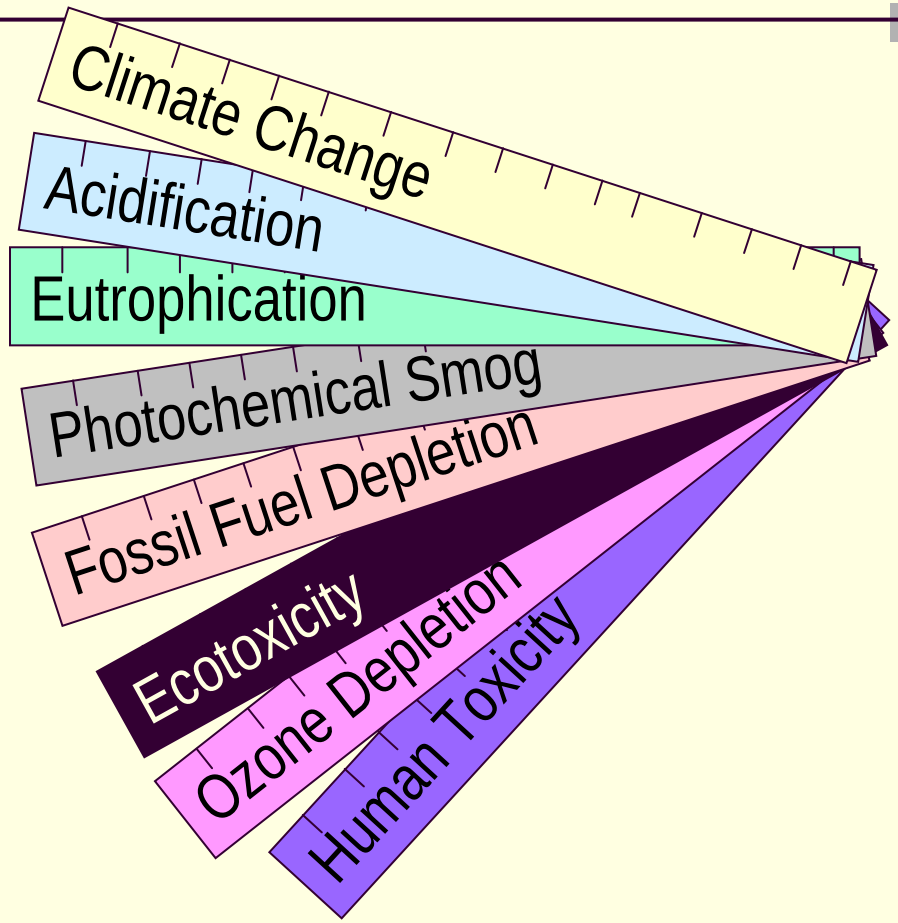
Systems Analysis; Input-output Life Cycle Inventory



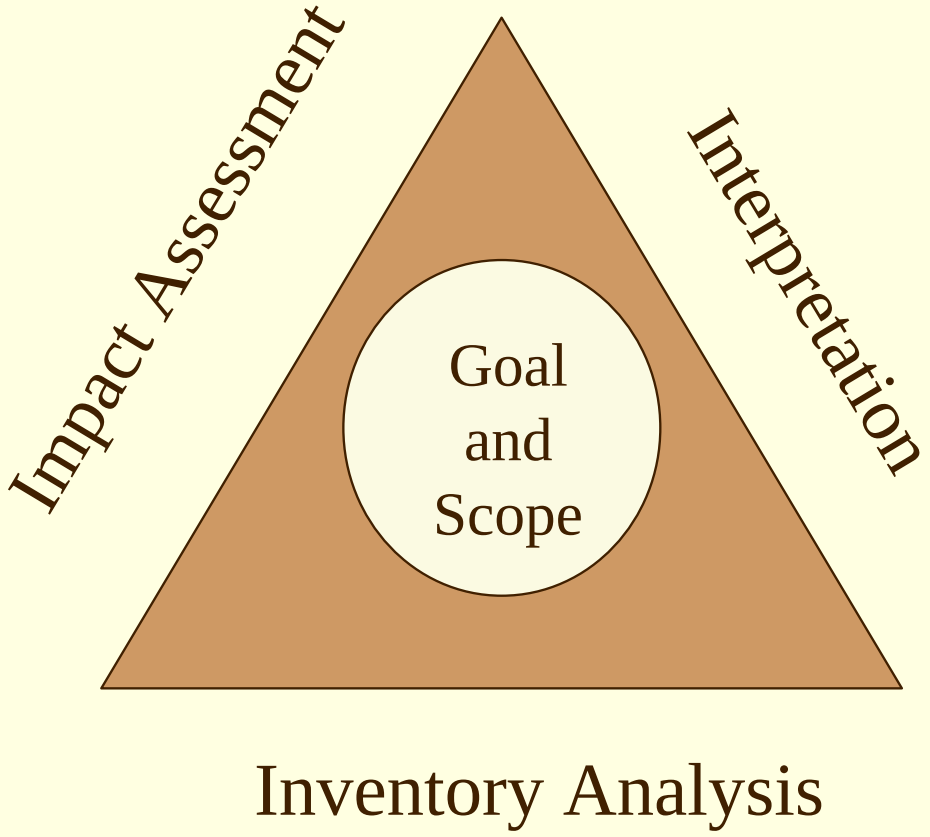
Industrial System

The science of measuring the environmental performance of products & services

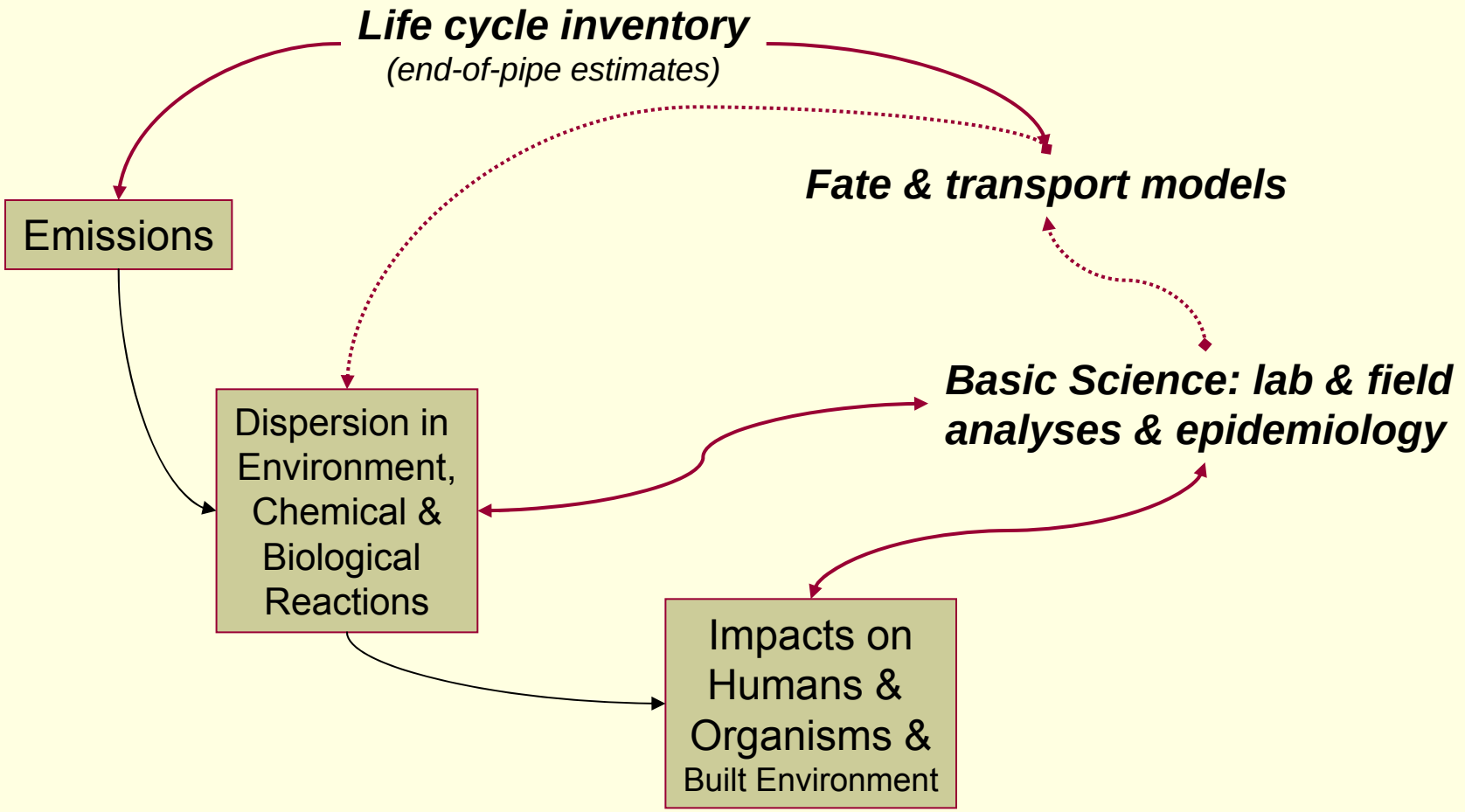
Indicators of All Impact Categories



Phases of a Life Cycle Assessment

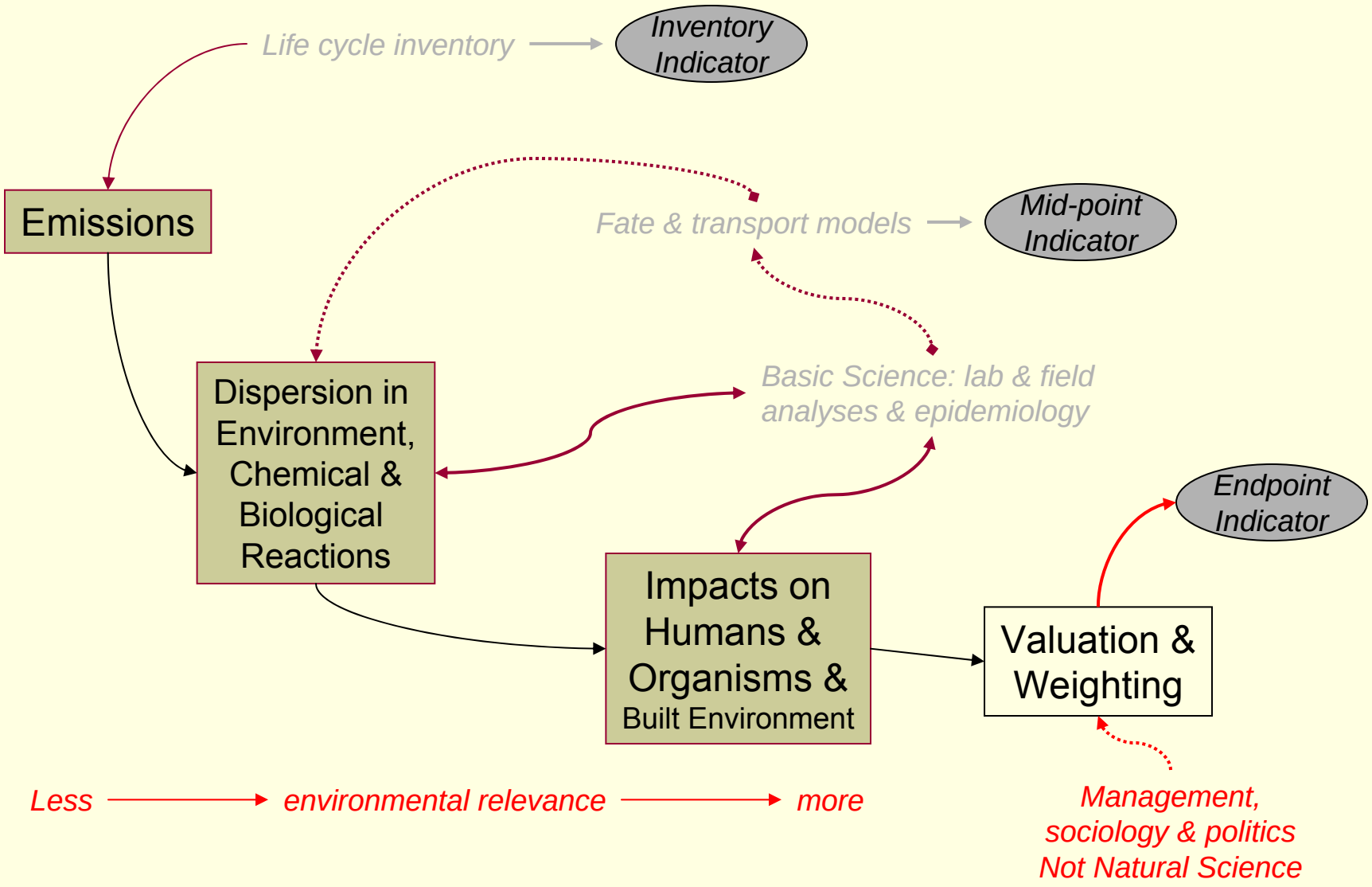


Impact Assessment: The Science



The Science elucidates the environmental mechanism

Life Cycle Impact Indicators



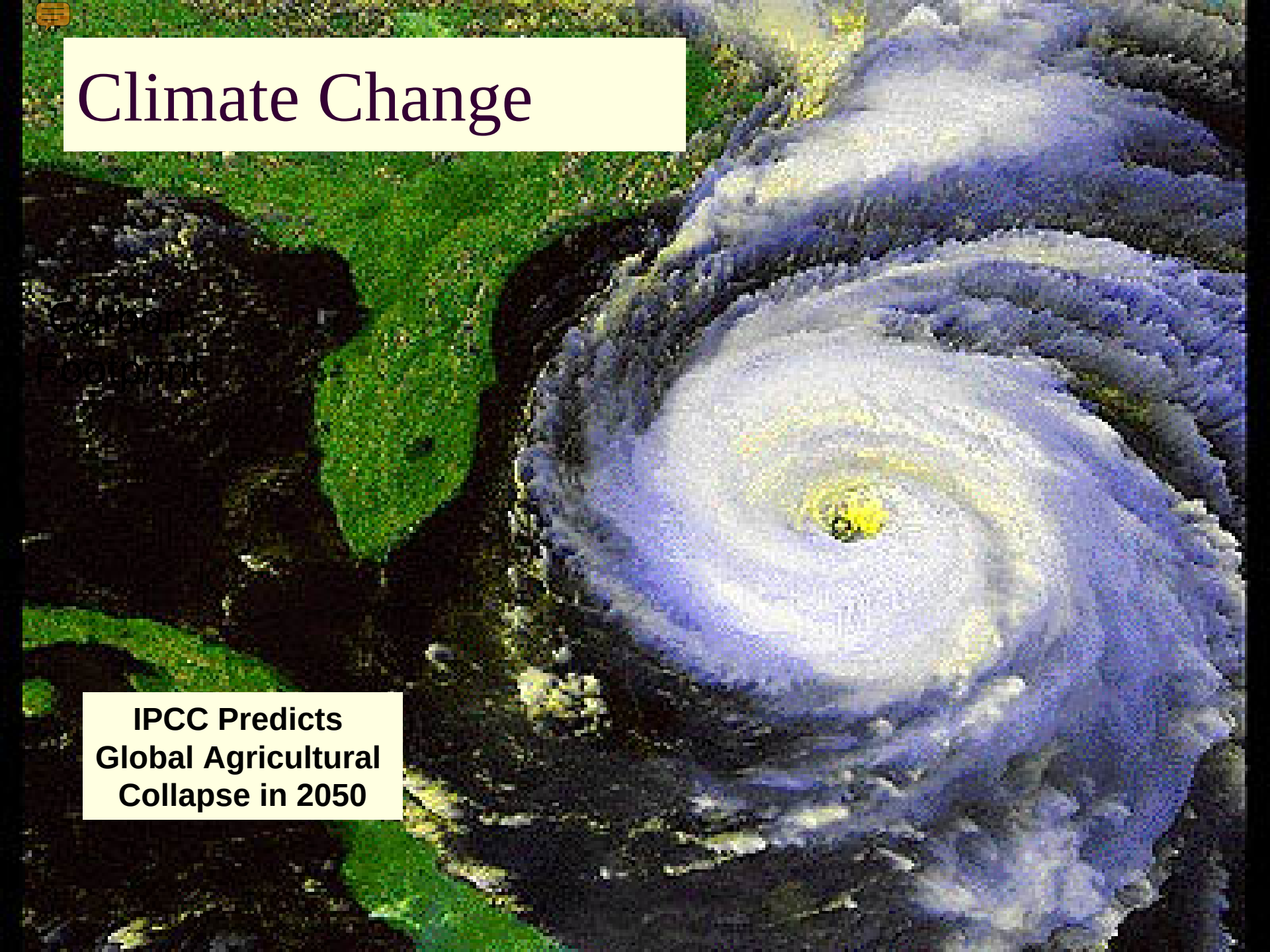
Before you do an LCIA

- Decide if the LCI data is adequate
- Decide which impact categories you will assess
- Describe the environmental mechanism
- Decide what are the endpoints you will use for each impact category
- Decide which models you will use

Typical Environmental Impact Categories

- Climate Change
- Stratospheric Ozone Depletion
- Eutrophication
- Photochemical Smog
- Acidification
- Human Toxicity
- Eco-Toxicity
- Water Resource Depletion
- Mineral Resource Depletion
- Fossil Fuel Depletion
- Land Use/Biodiversity
- Soil Conservation

Climate Change



IPCC Predicts Global Agricultural Collapse in 2050

Carbon Footprints are Part of Every LCA

Energy Source	Grams CO_2 Equivalents/kWh
Coal	1100 - 1300
Natural Gas	450 - 550
Hydro	1 - 5
Nuclear	10 - 20
Wind	5 - 50
Tidal	22
Solar	10 – 100

Smog

Estimated one million deaths per year, 60% in Asia

Acidification

1908

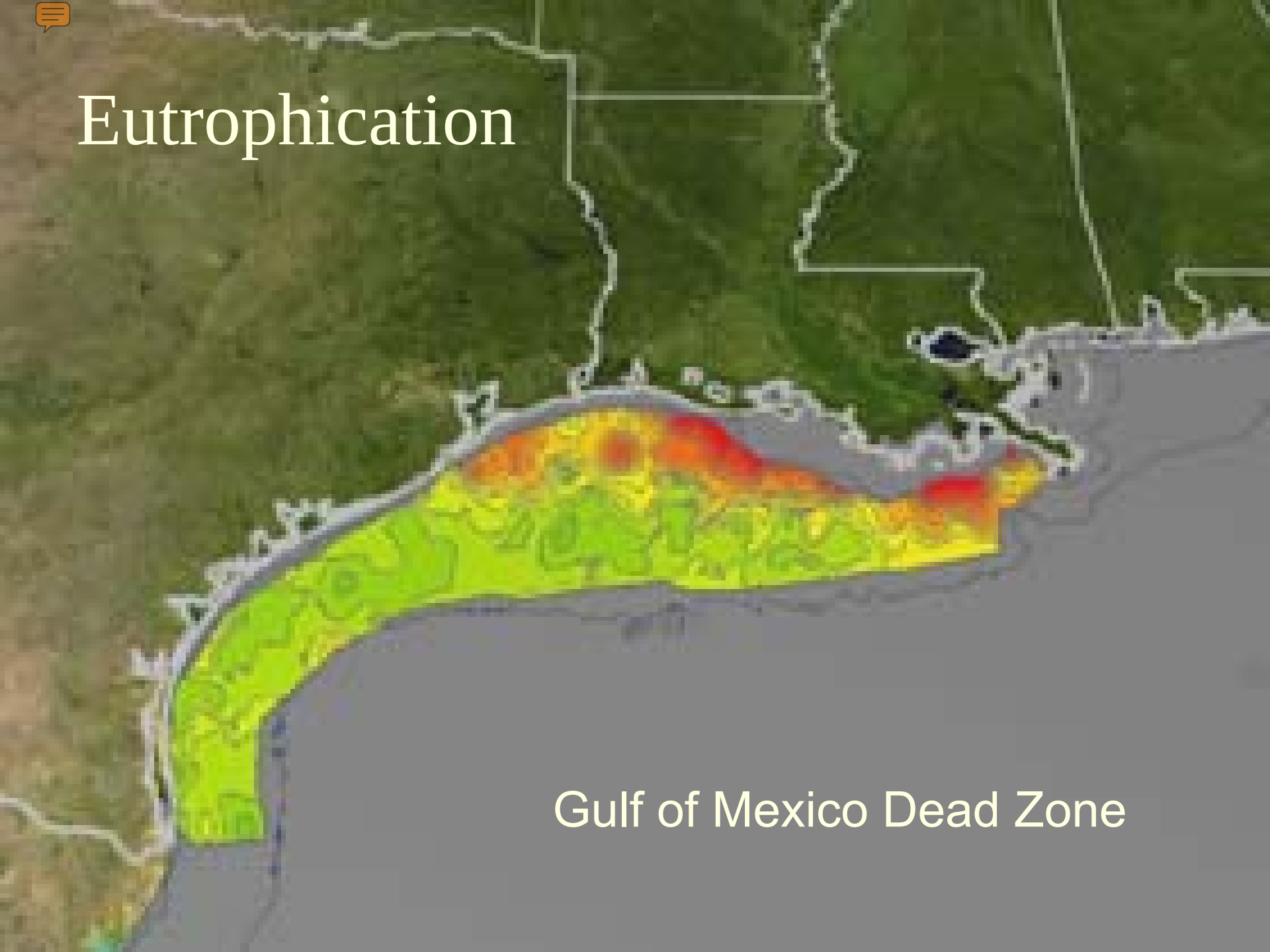
1968

Photos courtesy of Herr Schmidt-Thomsen

Land Use/Biodiversity

40% of the land surface
of the globe is in agricultural use
0.5% of forests lost per year

Eutrophication



Peak Oil: Fossil Fuel Depletion

- Oil resources are being depleted– we are near the end of the total earth stock of petroleum

Kjell Aleklett

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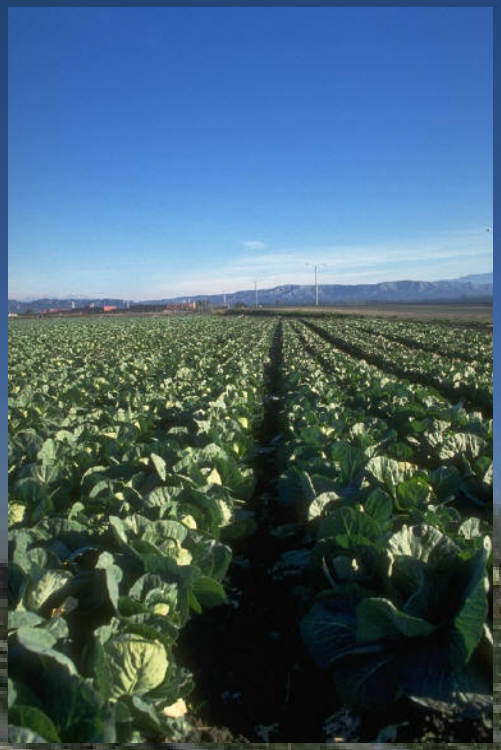
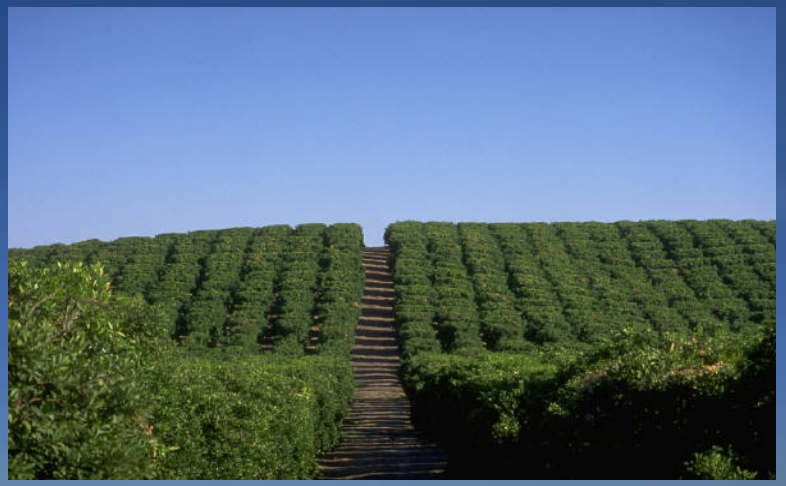
Water Depletion

70% of the world's freshwater is used for irrigation

Soil Conservation

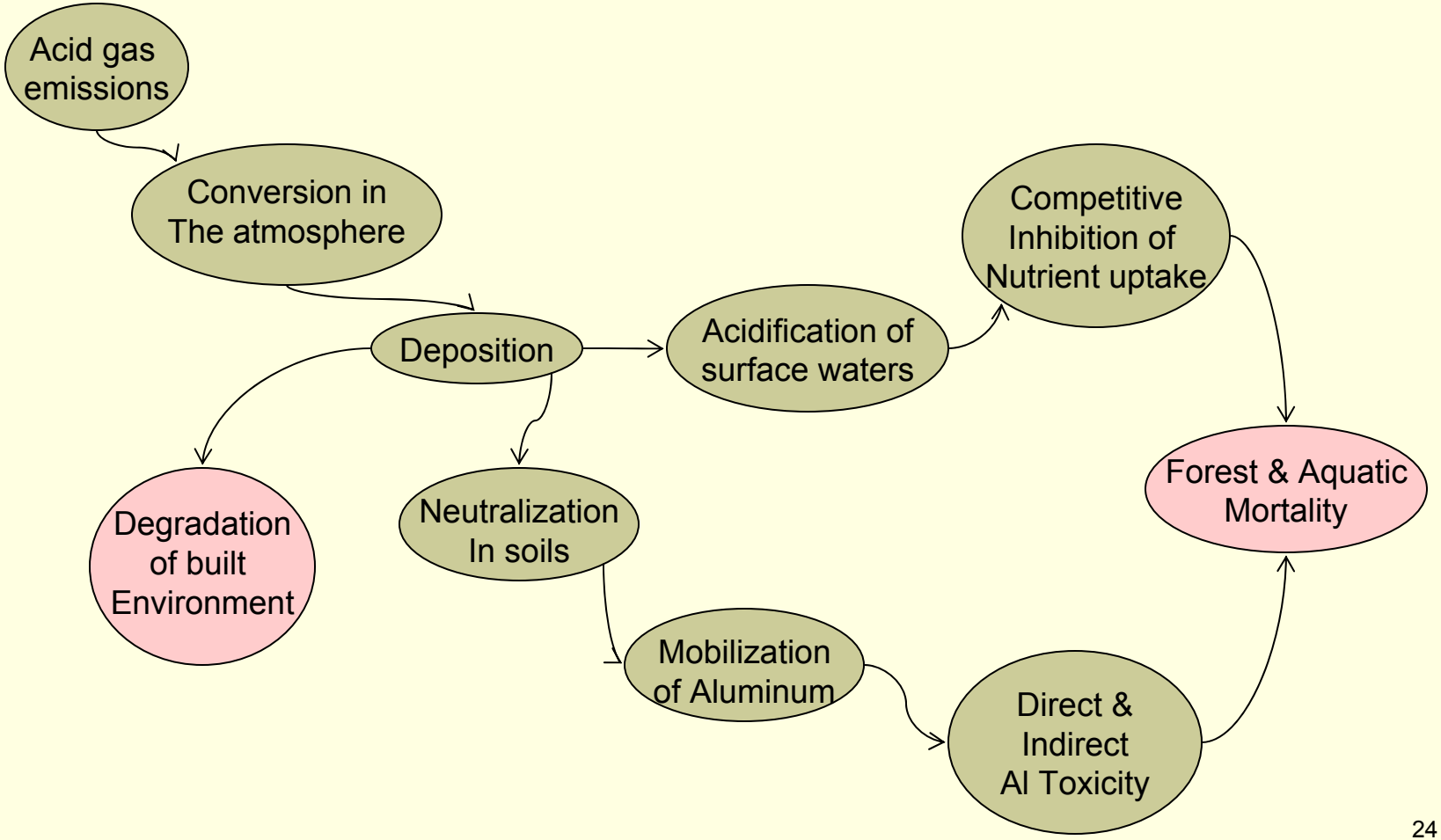




Questions?

Acidification

Simplified environmental mechanism of acidification



Simple Acidification Model

Σ_n (Mass emissions$_a$ x characterization factor$_a$) = impact indicator result

100 grams SO_2 x 0.03125 = 3.125 grams H^+ equivalents

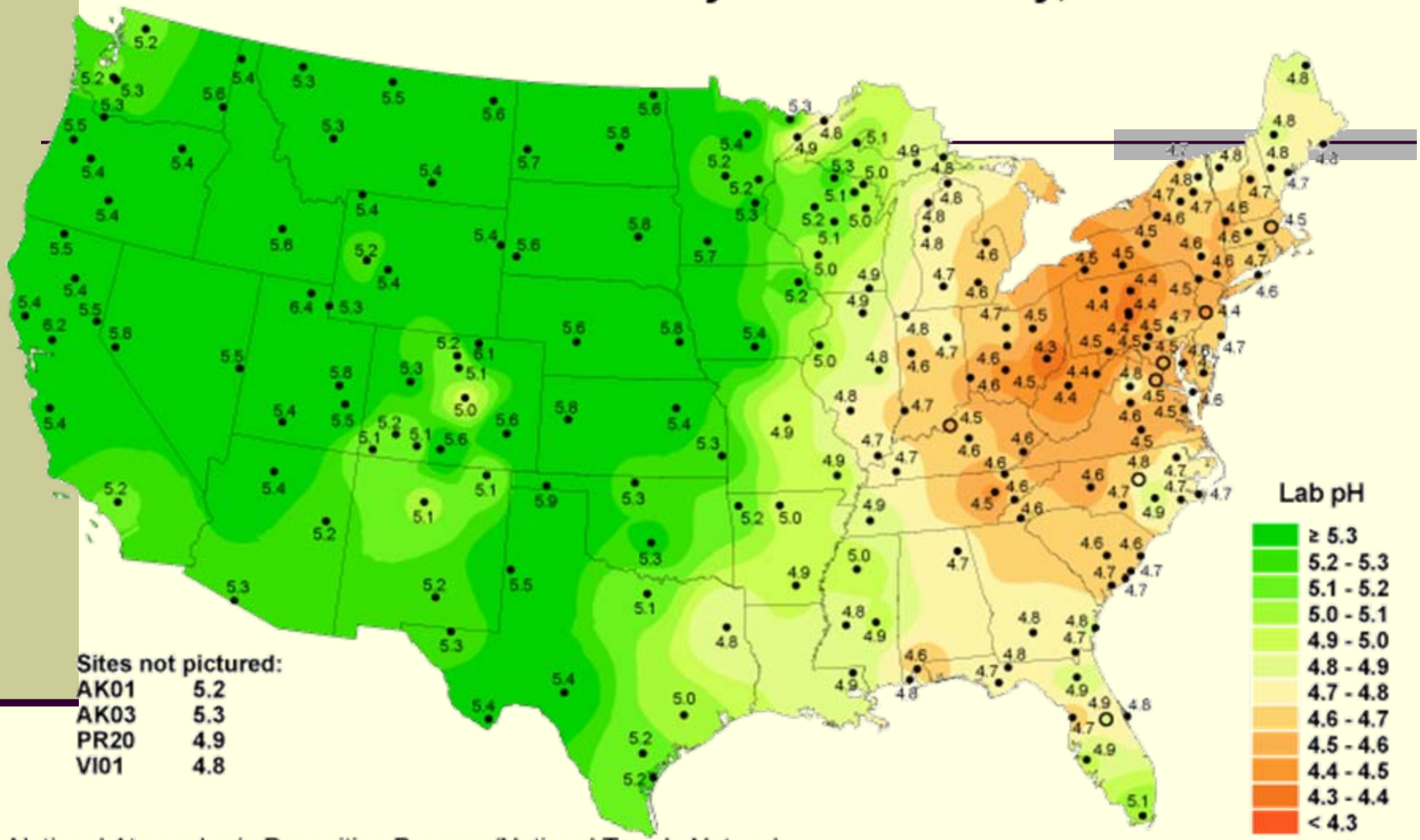
100 grams NO_2 x 0.0217 = 2.17 grams H^+ equivalents

100 grams HCl x 0.02778 = 2.778 grams H^+ equivalents

Total 8.1 grams H^+ equivalents

Stoichiometric ratios

Hydrogen ion concentration as pH from measurements made at the Central Analytical Laboratory, 2006

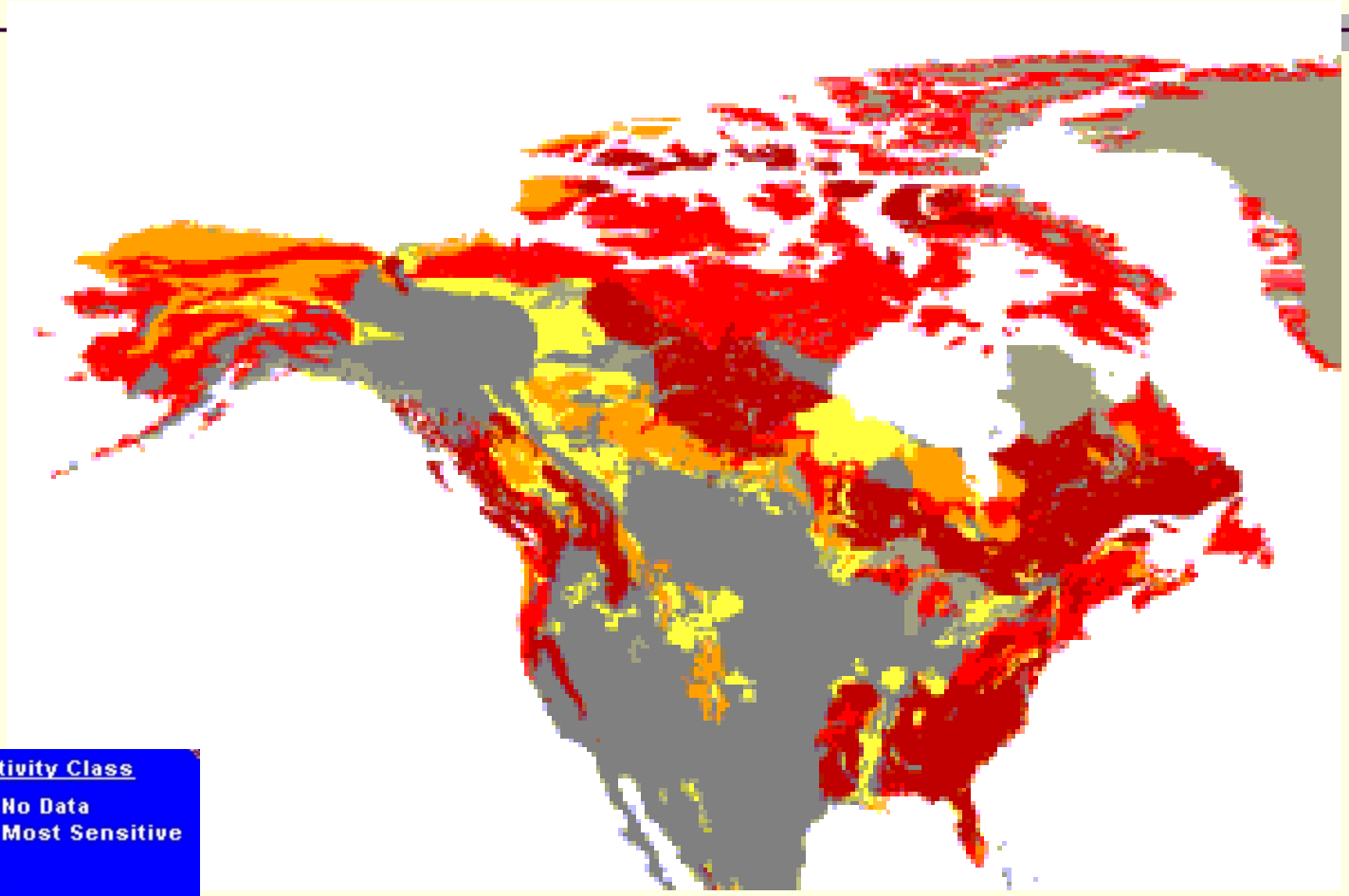


Sites not pictured:

AK01	5.2
AK03	5.3
PR20	4.9
VI01	4.8

National Atmospheric Deposition Program/National Trends Network
http://nadp.sws.uiuc.edu

Sensitivity to Acid Deposition (SEI)



Calculating the Acidification Emissions Indicator (threshold model)

- Calculate stoichiometric equivalencies
- Use dispersion model to calculate where things deposit
- Gather information about sensitivity of receiving environment
- Calculate how much of the emission exceeds threshold for effects

Threshold Emission Indicator Calculation

$$\Sigma\left(\text{Mass emission} \times \text{Stoichiometric Char.Factor} \times \text{Deposition Char. Factor}\right) = \text{Indicator}$$

			Stoichio-metric factor		Fraction deposited in sensitive areas			
100	g SO_2	x	0.03125	x	0.6	=	1.875	grams H+ equivalents
100	g NO_2	x	0.0217	x	0.4	=	0.868	grams H+ equivalents
100	g HCl	x	0.12778	x	0.2	=	2.5556	grams H+ equivalents
					Total	=	5.3	grams H+ equivalents

Example: RAINS model in Europe

Example of LCIA profile: Different Ways to Power Cars

Impact Category	Electric Grid			Gasoline	Units
	Coal	NG	Pet.		
Climate Change	450	270	440	480	gm CO_2 equivalents/mi
Acidification	0.031	0.01	0.11	0.011	gm H^+ equivalents/mi
Eutrophication	0.046	0.03	0.13	0.048	gm PO_4 equivalents/mi
Smog	0.001	0.01	0.02	0.26	gm O_3 equivalents/mi
Total Energy	4,000	4,100	5,000	6,200	BTUs/mi

From GREET

Sources of impact models

- US EPA TRACI models
- CML (Netherlands) Models
- SETAC/UNEP Life cycle initiative models
  - New models being developed all the time

Models are only as good as the science behind them: we can only model what we know

About Impact Categories

- Should not be arbitrary
- More important to be comprehensive than to be precise (otherwise you look like you are greenwashing)
- Best not to have overlap of impacts
- Must be able to explain why certain impacts are left out

After Impact Assessment

- Grouping, Normalization, Weighting, **Scoring** and other methods
- Used to clarify data for decision makers
- Based on **value judgments**, not science
- ISO standards require disclosure of results before any of these methods are applied

This is a voluntary, not mandatory set of techniques

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Grouping Environmental Impact Categories (1)

Pollution

- Climate Change
- Stratospheric Ozone Depletion
- Eutrophication
- Photochemical Smog
- Acidification
- Human Toxicity
- Eco-Toxicity

Resource Depletion

- Water Resource Depletion
- Mineral Resource Depletion
- Fossil Fuel Depletion
- Land Use/Biodiversity
- Soil Conservation

Grouping Environmental Impact Categories (2)

Global

- Climate Change
- Stratospheric Ozone Depletion
- Mineral Resource Depletion
- Fossil Fuel Depletion

Regional/Local

- Water Resource Depletion
- Land Use/Biodiversity
- Soil Conservation
- Eutrophication
- Photochemical Smog
- Acidification
- Human Toxicity
- Eco-Toxicity

Grouping Environmental Impact Categories (3)

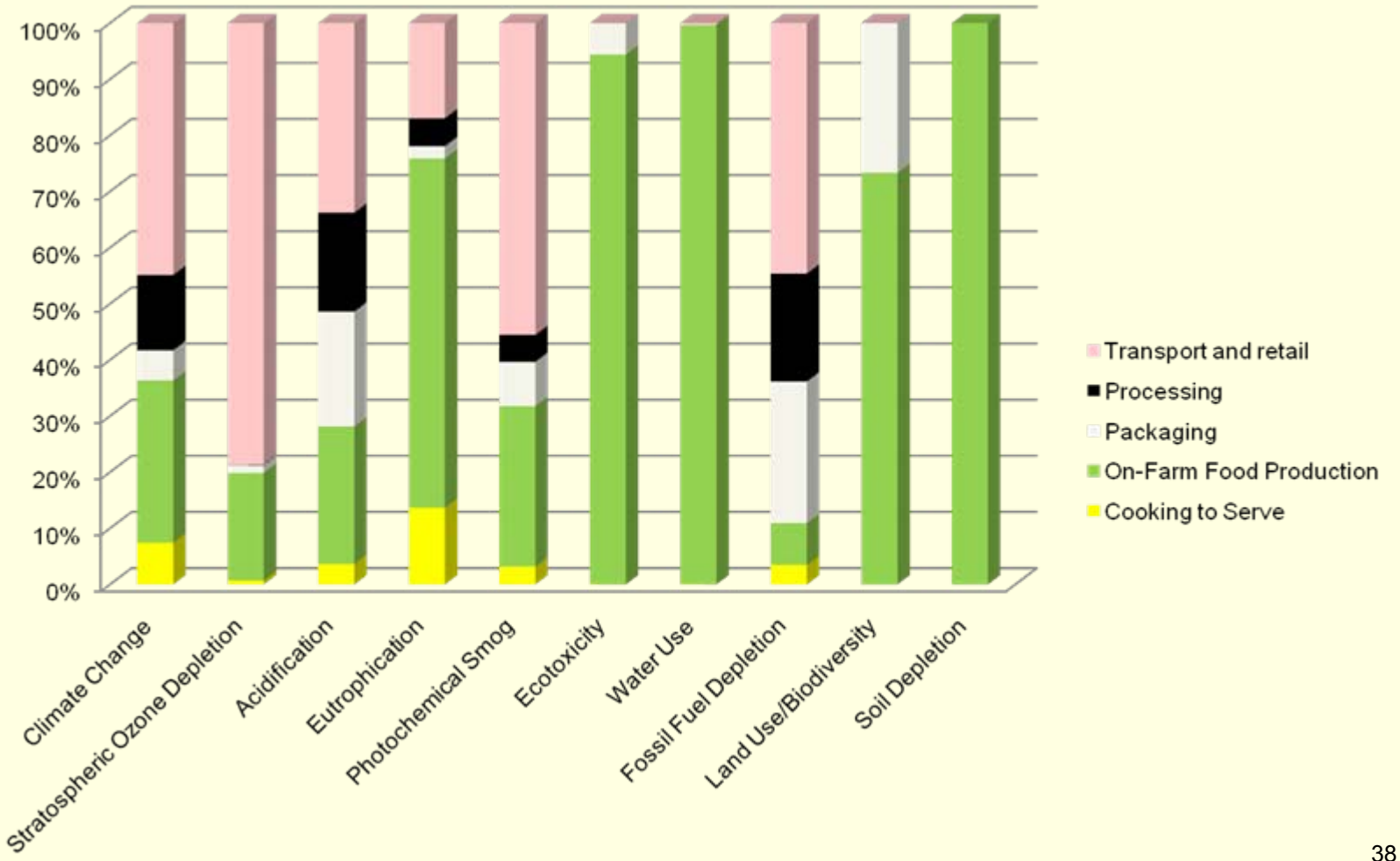
- High Confidence
  - Climate Change
  - Stratospheric Ozone Depletion
  - Mineral Resource Depletion
  - Fossil Fuel Depletion
  - Water Resource Depletion
  - Soil Conservation
  - Land Use
- Moderate Confidence
  - Acidification
  - Eutrophication
  - Photochemical Smog
- Low confidence
  - Human Toxicity
  - Eco-Toxicity

Normalization Examples

How important is something relative to something else

- Exxon is the source of 5% of total climate change since 1880's (per Earth Justice, 2004)
- The average American is the source of 5x as much and the average Canadian 6x as much Climate change as the average world citizen
- The forced percentile ranking of Wal-Mart packaging is a kind of Normalization

Truitt Brothers Chili with Beans Entrée Environmental Product Declaration



Normalization of life cycle stages to each other

External Normalization in LCA

- Commonly: Normalization to per-capita impacts
- The normalization must have the same units
  - Grams carbon to grams carbon
  - Tons acid equivalent to tons acid equivalent
- In the end, you have a unitless number

External Normalization Climate Change

- In 2007, there were 18 tons of CO_2 equivalents emitted per person in the U.S.
- The average gas fill up in the US creates about 0.18 tons of CO_2 equivalent.

0.18 tons per fill up ÷ 18 tons per person =
0.01 person-equivalents

External Normalization Acidification

- Average precipitation of acid rain is 58 kg H+/person per year in the US
- The average emission of acid rain due to a fill up of gas is about 0.0034 kg

0.0034 kg H+ per fill up ÷ 58 kg per person per year = 0.0006 person-equivalents

Normalized Addition

- Climate change per tank
  - 0.01 person-equivalents
- Acid Rain per tank
  - 0.00006 person-equivalents
- Total = 0.01006 person-equivalents

Weighting Example

Relative Importance Weights of TRACI impact categories based on Science Advisory Board Study

Impact Category	***Relative Importance Weight (%)***
Global Warming	16
Acidification	5
Eutrophication	5
Fossil Fuel Depletion	5
Indoor Air Quality	11
Habitat Alteration	16
Water Intake	3
Criteria Air Pollutants	6
Smog	6
Ecological Toxicity	11
Ozone Depletion	5
Human Health	11

Note: 39% of impacts are human only impacts

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Weighting & Scoring

Impact	Person equivalent	Weight	Score
Climate Change	0.01	16	0.16
Acidification	0.00006	5	0.0003
Total	0.01006		0.1603

Questions?

Interpretation Phase

- Reviews data quality
- Makes recommendations
- Not always done in LCA, or done cursorily (some important exceptions)

Interpretation

- identification of the significant issues based on the results of the LCI and LCIA phases of LCA;
- an evaluation that considers completeness, sensitivity and consistency checks;
- conclusions, limitations, and recommendations.

Sensitivity Analysis

- How much does the output and conclusion change with different assumptions about inputs to the model?
  - System boundaries
  - Missing data
  - Assumptions
  - Choices about the impact models

Example of a sensitivity analysis

- Typically, machinery manufacture is left out of the system boundary (it is assumed to be very small)

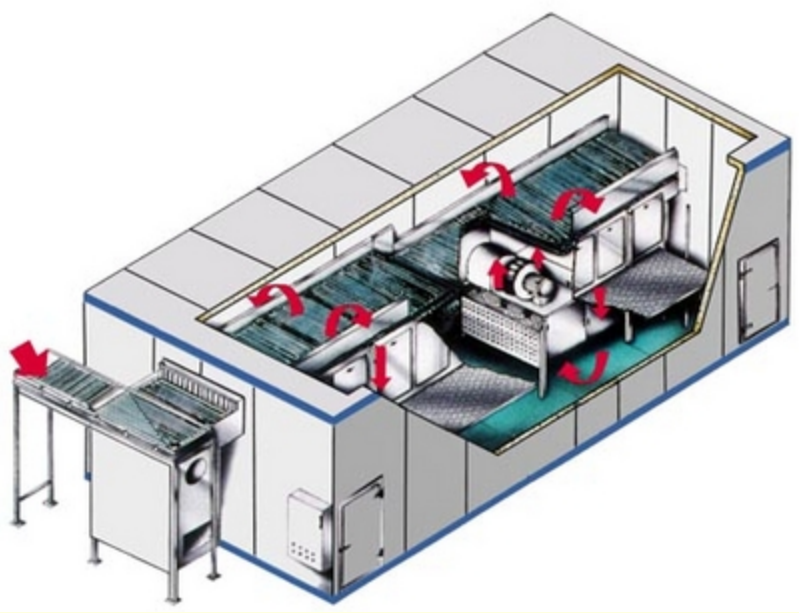
But it turns out that on farm, tractor manufacturing impacts may be quite large (because the tractors are used only a few weeks of the year)

Sensitivity analysis data gaps

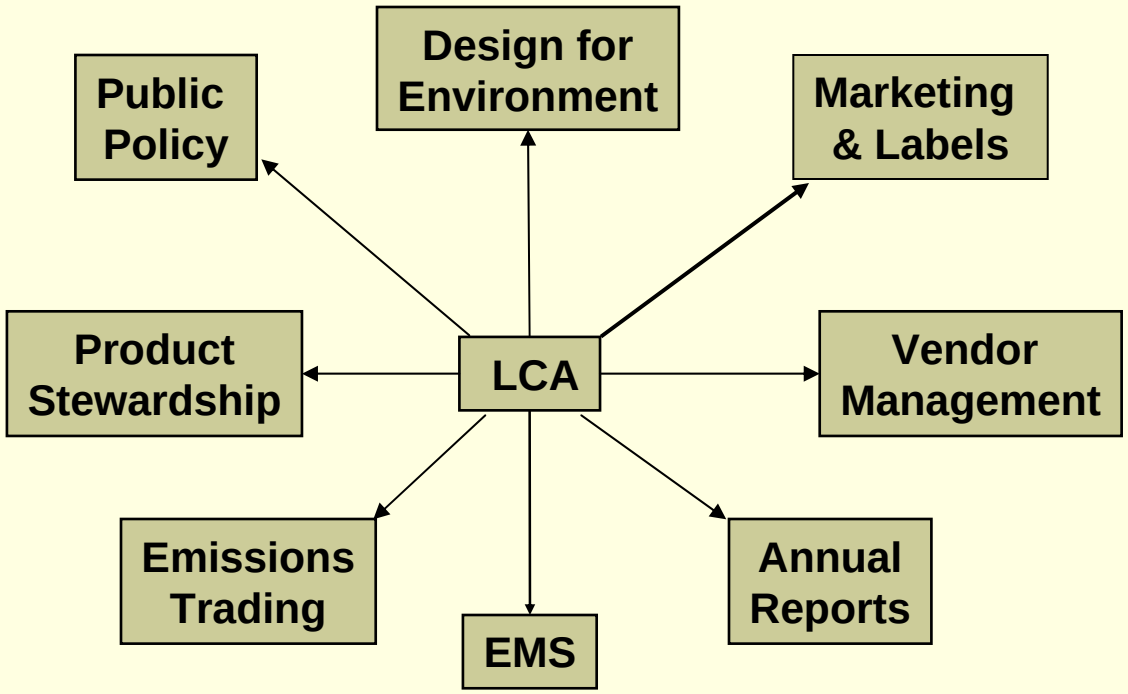
- Example: you are not certain how much energy it will take to run a machine, and can find only one literature citation.

- Perform a sensitivity analysis at 50% and 200% of cited energy use.

- Do the overall results change significantly?



Uses of LCA


Public Policy
Design for Environment
Marketing & Labels
Product Stewardship
LCA
Vendor Management
Emissions Trading
EMS
Annual Reports

Kyoto Protocol

- Cleaner development mechanism
- Industrialized nations can support projects in less developed nations to reduce carbon and meet their goals
- LCA is the methodology used to measure outcomes

LCA-based Laws in Europe

- 2003 Integrated Product Policy (IPP)
- 2003 End of Life Vehicles
- 2004 EU Directive on Packaging & packaging waste
- 2005 Waste Electrical and Electronic Equipment (WEEE)
- 2002 Restriction on the use of Certain Hazardous Substances in Electrical and Electronic Equipment (RoHS)
- 2006 Batteries Directive
- 2007 Registration, Evaluation and Authorisation of Chemicals (REACH)
- French Grenelle EPD requirements (2011)

Japanese LCA Based Laws

- Laws come from MITI (Ministry of Economy, Trade & Industry)
  - Kyoto Protocols– Climate Change
  - Recycling Oriented Economy
  - Chemical Integrated Policy (Hazardous Chemical Management)
- Japan's focus is internal
  - Development of Life Cycle Inventory (US$11MM)
  - Recycling in-country
  - Development of Type III ecolabel
  - Requiring carbon footprint EPDs in 2011-2012

Other Countries Considering LCA Approach

- Australia
- Canada
- China
- India
- Korea
- South Africa

USA Policy Use of LCA's

- In the Energy Independence Act of 2007
- In draft of new energy bills (carbon footprint)
- As policy backup in Oregon solid waste management (e.g. bottled water)
- Basis of California carbon law
- Basis of Green Building ordinance in King County

In Summary

- LCA is an environmental performance measurement tool
- It has many uses both internal and external, business and governmental
- It is used all over the globe
- EPDs and carbon footprints are growing application

Questions?